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ON MUSCULAR MEMORY.

BY THEODATE L. SMITH.

While a vast amount of minute and laborious study has been given to the investigation of the sensory side of psychical activity, experimental research has as yet accomplished relatively little in the realm of central psychology. This is due partly to the fact that in the order of genetic development the senses come first, and partially also to the increasing difficulty of reducing the more complex mental processes to experimental terms.

Memory, imagination, attention, will, and the affective states furnish but short chapters in the history of experimental psychology in comparison with the numerous and sometimes dreary pages which record the patient and painstaking labor of the psychophysicists. Yet it is to these unfinished chapters that pedagogy looks for the aid which it rightfully seeks from psychology, and it is here that psychology must find its practical justification.

The present research was suggested by an incident in connection with Edith Thomas, a child deaf and blind from her fourth year, and, at the time of the incident, about nine years old. This child was tested by Professor Graham Bell of Washington as to her ability to reproduce by motor imitation the movements of the throat and mouth involved in articulate speech. She succeeded fairly well, pronouncing

the letter K, which offers peculiar difficulty to deaf mutes, with unusual distinctness. When asked to repeat the letter some hours later, she called with an almost perfect enunciation, "Kitty, Kitty, Kitty." Investigation revealed the fact that when at the age of four years the gradual loss of speech had followed that of sight and hearing, the last intelligible word spoken by the child was "Kitty." The reproduction was unconscious, the child having absolutely no idea of what she had done. It was not, then, a reproduction of the word as heard or as associated with something seen, but of a muscular movement, which, latent for five years, was recalled by the suggestion of a similar movement. This incident suggested that possibly, under normal conditions, the muscles play a greater part in our memories than we are accustomed to assign to them.

Every teacher has observed children busily moving their tongue and lips during the memorizing of a lesson, perhaps without thinking that the movement was not a mere habit, but a real aid in the process of memorizing. One case has been reported to me of a teacher who reproved a child for moving his lips, and added, by way of explanation, that it was a bad habit and prevented giving full attention to the lesson. Anyone can find in his own experience familiar examples of memorizing done by the muscles; music, of which not a note can be recalled by sight, and whose auditory image is indistinct, may yet reside in the fingers.

The movements of writing, walking, dancing, and repetition of familiar phrases, all tend to become automatic, that is to say, we dismiss them from the higher cortical centres where consciousness is an accompaniment, to the keeping of the lower centres whose functioning is attended by a minimum of consciousness.

In such cases the motor idea itself sinks below the threshold of consciousness and only the expression remains. As to the dependence of the movement for its reproduction on the motor idea, we have only to recall the difficulty which we experience in attempting to make any muscular movement of which we have no previous experience, and therefore no clear mental image of it, in order to realize that the

mental image of a motion and the actual movement are but two sides of one process. Prof. James' familiar statement that we learn to skate in summer and to swim in winter, is an illustration of this. In this connection also, it is an interesting fact noted by Major Powell that those Indian tribes whose religious rites are connected with dancing, say of the uninitiated, "He does not understand it, because he has not danced it out."

These miscellaneous facts were all suggestive that the influence of the muscular or motor element in memory might be reduced to a laboratory problem and investigated by experimental methods.

The amount of experimental work on Memory already accomplished is very small. Investigations of the effect of repetition and rhythm,[1] the memory span,[2] and some comparisons of the relative value of the disparate senses,[3] chiefly sight and hearing, in memory constitute the principal points toward which research has been directed. The Memory of tones has been investigated by Wolfe.[4] The first psychologist to attempt a definite memory problem was Hermann Ebbinghaus, who undertook and carried out in person a series of experiments little short of heroic.

Out of the eleven vowels and diphthongs and the simple consonants of the German alphabet, he formed twenty-three hundred syllables, each composed of a vowel or diphthong between two consonants. These he mixed together, and, picking them up without prearranged order, formed series of varying lengths. His experiments were chiefly upon the memory span and the effects of repetition. His method of learning the syllables was to read aloud in a monotonous voice series of nonsense syllables of various lengths, regulating the rapidity of reading by the strokes of a metronome, until the series could be just reproduced without error. In case of an error, the series was read through to the end and a fresh beginning made. The number of repetitions neces-

[1] Ebbinghaus, "Ueber das Gednächtniss." Leipzig, 1895.
[2] Jacobs and Bryant, *Mind*, XII, pp. 75 seq.
[3] Münsterberg & Bigham, *Psychological Rev.*, Vol. I, p. 453.
[4] Wolfe, "Ueber das Tongedächtniss."

sary for series of different lengths was recorded, and after certain intervals of time, varying from ten minutes to one or two days, or even longer periods of time, the number of repetitions necessary for relearning the syllable was recorded.

By this means he obtained a standard for measuring the degree of forgetfulness. It was found that the process of forgetting was, at first, slow, and then progressed more rapidly, and finally very slowly again. An hour after the series had first been memorized, the process of forgetting had so far advanced that more than half the time originally employed was necessary for relearning the series. After eight hours had elapsed, two-thirds of the original time was required for relearning, and a month later about four-fifths. These numerical relations Ebbinghaus expresses approximately by the following formula: "The quotients of the amounts retained by the amounts forgotten are to each other inversely as the logarithms of the various periods of time that have elapsed."

In memorizing poetry Ebbinghaus found that the verses of a given poem (Don Juan) can be retained ten times as easily as a series of nonsense syllables of similar length. While this precise statement is questionable, it undoubtedly exemplifies the law that associated ideas are far more easily retained than dissociated ones, as in the case of nonsense syllables.

This research of Ebbinghaus remained the only important experimental work on memory until the work of Müller and Schumann (published in 1893 in the *Zeitschrift für Psychologie*). This work was an investigation of the methods of Ebbinghaus. Ebbinghaus' experiments had all been made upon one subject, himself, and without any special investigation of the effects of rhythm and association upon his series of syllables. Müller and Schumann made these points the subject of minute and careful investigation, their experiments extending over a period of nearly five years. The following very brief summary gives the more important results of their work. In series of syllables taken in the promiscuous order of Ebbinghaus, the following effects of association are observable:

Ease of learning is increased,

I. If two or more successive syllables have the same initial consonant;

II. If two successive syllables form a rhyme;

III. If two successive syllables contain the same vowel or diphthong;

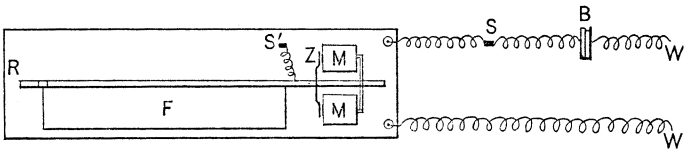
IV. If the final consonant of a syllable is the same as the initial consonant of the syllable immediately following;

V. If two or more syllables form a word or phrase, or if the syllable itself is a word.

VI. Unusual combinations and those especially difficult to pronounce were a hindrance to learning.

VII. Rhythm was found to have a distinctly favorable influence upon learning; syllables which had once formed part of a metrical foot tending to be associated more closely in all future combinations than syllables not so united.

To the authors of all this detailed and laborious work upon the material and method of memory work, the thanks of later investigators are due, and with this material, nonsense syllables, formed and arranged in accordance with the results of Müller and Schumann and altered so as to adapt them to the English language, the first experiments of the present problem were made.



Z = ⟨-shaped piece of metal.
B = battery.
S = switch.
M = magnets.
R = rotating bar.
F = shutter.
S′ = spiral spring.
W = wires leading to clock.

Description of Apparatus.

An automatic shutter, devised by Dr. E. C. Sanford, was used as the means of presenting the different series to the subject. This consisted of a board which could be tilted at any convenient angle, to which was fixed by brass supports a rotating bar. To this was fastened a strip of pasteboard of

convenient size. At the end of the bar were a pair of magnets, brought into connection with the rod by an ⟨-shaped piece of iron.

An electric circuit being made, the attraction of the heaviest part of the metal toward the centre of the magnets caused the rotation of the bar and raised the strip of pasteboard. A light spiral spring fastened to an upright screw regulated the force of the movement, and threw the shutter back when the circuit was broken.

This shutter was electrically connected with a pendulum clock movement, to which were attached two commutators, each consisting of a rubber disc having eighty degrees of brass let into the circumference. Connection was made by two strips of metal fastened to the framework, and so bent as to touch the discs. The clock movement was so adjusted that each disc made one complete revolution in ninety seconds, and in such relation to each other that the circuit was made in one, two seconds earlier than in the other. The former was connected with an ordinary telegraph sounder and the other with the shutter. The clock being set in motion, a warning signal was given to the subject by the sounder, and two seconds later the shutter was raised and remained up for twenty seconds, the warning signal being repeated two seconds before its fall. The clockwork was placed in a separate room, and wires carried across to the shutter, in order that the attention of the subject might not be distracted by the ticking. A switch was introduced into the circuit, so that the interval of the break could be doubled or tripled if desired.

In the present research two points in the problem have been considered :

I. To investigate the complex of throat, tongue and lip movements involved in articulation, and to determine their influence upon the memory of syllables.

II. To investigate the muscle memory proper, *i. e.*, memory of movements.

In carrying out the proposed series of experiments, conditions were made as normal as possible consistently with the demands of experimentation. The subject was comfortably seated in a well-lighted, quiet room and a screen placed be-

tween him and the experimenter, so that extraneous ideas might be excluded as far as possible.

Experiments of the First Series.

The first experiment proposed was to find some means of inhibiting the action of the muscles involved in articulation, in order to compare the series thus learned with those learned under normal conditions.

Various means of inhibiting the movement of the muscles of the throat and mouth were tried. The subject was required to memorize while counting aloud,—one, two, three, one, two, three,—practice being continued until the counting became as nearly automatic as possible. Similar experiments were also tried, using a sustained musical note as the means of inhibition. The syllable *sol* was used as inhibiting action in a greater number of muscles than any other syllable used in musical notation.

In a series of one hundred experiments, each with the counting and sustained musical note, the per cent. of difference in the results was so small as to be practically negligible. The counting was finally adopted as the better method, because unmusical subjects proved to be somewhat diffident about sustaining a musical note, and so required more preliminary practice to overcome the distraction of attention due to this cause.

Each series of syllables was shown for twenty seconds, the subject being requested to repeat aloud as many as he could remember as soon as the shutter was closed. Errors were recorded under three heads :

I. Displacements in the order of the series. II. Wrong syllables. III. Forgotten syllables.

Under this last heading a subdivision into syllables omitted from portions of the series, and those forgotten at the end of the series, was made. This was done for the purpose of checking any tendency on the part of the subject to give more attention to one part of the series than another, the record of errors immediately showing any tendency to devote attention to the first five or six syllables instead of reading the whole series evenly. The subject was always experimented on at

the same hour of the day, and as nearly as possible under the same conditions of health, fatigue, exercise, etc., a record being kept of any deviation from the usual conditions.

The actual experiments from which results have been tabulated were made upon five subjects, one of whom was a trained psychologist, two had had several years of general practice in psychological experimentation, one was entirely unaccustomed to psychological work, and one, though unpracticed in psychological work, was of scientific training in biological work. All were given a sufficient amount of special practice to render the counting as nearly automatic as possible, and to reduce the mean variation of their records to a minimum. The daily hours of experimentation for each person were the same, an important precaution, as the memory curve varies greatly at different hours of the day.[1]

Each subject was given one hundred syllables, that is, ten series consisting of ten syllables each, at one sitting. This number was decided upon after various trials, which proved that a greater number of experiments at one time brought in an element of fatigue which rendered the record unreliable. At first, series with and without counting were alternated, but as this was found to produce interference on account of a tendency of the subject to count during the learning of series to be learned without counting, a change was made to the method of giving ten series with counting on one day, and ten series without counting on the following day. No series was ever repeated, as after once having been recited the auditory element was introduced. A careful record was kept of the physical and mental condition of the subject, and any series showing a marked degree of variation from the normal, which could be accounted for as the result of fatigue, inattention or extraneous disturbance, was excluded from the final averages. Each subject was requested at the close of an experiment to report any introspective observations of chance associations, such as nicknames or suggested words, and especially anything connected with the motor images. Many valuable hints were gained in this way. The following fact

[1] Cf. Bergström, AM. JOURNAL OF PSYCHOLOGY, p. 245.

was reported by all five subjects. At first, the counting produced actual inhibition of the motor image as well as of the overt act. To illustrate this, let anyone try the experiment, quoted by Prof. James[1] from Stricker, of trying to pronounce mentally the word "bubble" with the lips held widely apart so as to effectually prevent any attempt at actual pronunciation, or holding the throat open, as in yawning, attempt to mentally pronounce "giggle." It will be found that at first the mental image is blurred and indistinct. After practice, however, the motor idea became separable from the actual muscular movements, and it became possible to pronounce the syllables mentally with greater or less distinctness, while the muscles through which the motor idea would normally discharge were actually occupied in the movements of counting.

None of the five subjects exhibited the distinct types of visual, auditory and motor memories, so emphasized by Ribot and the French school of psychologists, but two of them, brother and sister, showed a somewhat marked predominance of the motor element, as is shown by the tables, and these two complained of some blurring of the mental pronunciation, especially if the combination of letters was an unusual one, or presented marked difficulty of pronunciation.

The presence of the motor image of the syllables during the counting was also shown by a tendency of the syllables to interpolate themselves in the midst of the counting. Cases of this occurred repeatedly in all five subjects, most frequently in the slight breaks of the counting caused by taking breath, but also at other times. In a few cases, the subject when questioned at the close of a series had no recollection of the interpolation. Whether there was consciousness of the error at the time it was committed cannot be stated, as no questions were asked until after the series had been recited.

The following tables are based on the record of the total number of errors made by each subject for one thousand syllables, the vertical columns showing the number of errors for each series of ten, taken in the order of presentation. The

[1] "Psychology," Vol. II, p. 63.

footing of the vertical columns shows the average error for each day's record of one hundred syllables. The averages taken horizontally give the average of error for the series taken in the order of their presentation, *i. e.*, for the total number of series presented, first, second, third, etc. The summation table shows the percentage of difference in the series due to the counting.

Subject J. P. H. Table showing the errors for 100 series of nonsense syllables with pronunciation inhibited by counting.

Dec.10.	13.	16.	20.	Jan. 3.	7.	9.	14.	24.	28.	Av.
6	7	8	8	6	8	7	7	9	7	7.3
8	7	9	9	8	8	8	10	8	9	8.4
8	8	8	8	8	8	8	7	10	8	8.1
8	9	8	8	8	10	8	8	8	6	8.1
6	6	8	9	8	8	8	8	8	7	7.6
5	8	7	8	7	6	9	8	8	8	7.4
6	8	8	7	7	7	7	9	8	7	7.4
6	8	7	8	8	9	8	8	8	9	7.9
8	8	9	8	8	8	8	6	8	10	8.1
8	7	8	8	8	10	8	8	8	6	7.9
6.9	7.6	8.0	8.1	7.6	8.2	7.9	7.9	8.3	7.7	7.82

Subject J. P. H. Table showing the errors for 100 series of nonsense syllables under normal conditions.

Dec.12.	19.	Jan. 8.	10.	15.	16.	21.	22.	25.	29.	Av.
6	5	5	6	7	8	7	7	7	7	6.5
6	6	6	6	7	8	7	5	7	7	6.5
8	8	6	7	5	7	7	5	7	7	6.7
6	5	8	5	7	7	7	7	8	5	6.5
7	6	7	4	8	6	7	6	7	7	6.5
6	7	5	6	6	8	6	8	6	6	6.4
8	7	7	6	6	6	7	6	6	6	6.5
6	6	8	6	7	7	8	6	8	5	6.7
5	7	6	5	5	7	8	7	6	7	6.3
6	6	8	6	5	7	7	6	6	6	6.3
6.4	6.3	6.6	5.7	6.3	7.1	7.1	6.3	6.8	6.3	6.49

Table showing classification of errors given in two preceding tables.

Subject, J. P. H.	(c)					(o)			
	F.	D.	W.	Total.		F.	D.	W	Total.
Dec. 10th	39	4	26		Dec. 12th	38	6	20	
" 13th	56	6	14		" 19th	36	2	25	
" 16th	50	6	24		Jan. 8th	42	2	22	
" 20th	57	7	17		" 10th	38	2	17	
Jan. 3rd	56	6	14		" 15th	37	3	23	
" 7th	57	3	22		" 16th	40	4	27	
" 9th	57	–	22		" 21st	40	4	27	
" 14th	58	3	18		" 22nd	39	3	21	
" 24th	56	6	21		" 25th	40	2	26	
" 28th	51	4	22		" 29th	36	–	27	
	537	45	200	782		386	28	235	649

(c) = series with counting; (o) = normal series; F. = syllables forgotten; D. = syllables displaced; W. = syllables wrong.

Subject E. C. S. Table showing the errors for 100 series of nonsense syllables with the pronunciation inhibited by counting.

Dec. 2.	3.	6.	10.	13.	19.	Jan. 3.	7.	16.	23.	Av.
4	7	7	7	5	3	5	8	5	8	5.9
8	6	8	6	8	6	6	5	5	7	6.5
7	7	6	8	5	4	7	7	6	8	6.5
9	6	8	6	8	6	7	7	4	5	6.6
7	7	9	5	8	5	6	10	7	7	7.1
5	7	10	5	8	7	5	7	7	7	6.8
7	6	8	7	6	8	7	7	8	6	7.0
7	7	8	7	7	6	4	4	7	8	6.5
8	6	7	7	7	8	7	6	6	8	7.0
10	5	8	8	7	4	7	7	8	7	7.1
7.2	6.4	7.9	6.6	6.9	5.7	6.1	6.8	6.3	7.1	6.70

Subject E. C. S. Table showing the errors for 100 series of nonsense syllables under normal conditions.

Dec. 2	5.	6.	9.	12.	17.	20.	Jan. 6.	9.	21.	Av.
4	5	7	5	4	6	3	5	2	5	4.6
5	7	7	5	6	6	4	8	5	5	5.8
7	7	6	7	6	5	4	6	6	5	5.9
7	7	8	5	3	6	6	5	4	6	5.7
6	6	7	6	4	4	5	5	4	4	5.1
7	5	5	7	3	5	6	5	6	5	5.4
7	7	4	5	5	5	7	6	4	5	5.5
6	7	6	4	7	4	6	5	7	5	5.7
7	5	5	7	6	7	4	3	5	4	5.3
8	5	5	4	5	6	4	8	4	5	5.4
6.4	6.1	6.0	5.5	4.9	5.4	4.9	5.6	4.7	4.9	5.44

Table showing classification of errors given in two preceding tables.

Subject, E. C. S.	(c)					(o)			
	F.	D.	W.	Total.		F.	D.	W.	Total.
Dec. 2nd	51	4	17		Dec. 2nd	34	6	24	
" 3rd	25	7	32		" 5th	21	11	29	
" 6th	38	13	28		" 6th	20	11	29	
" 10th	31	6	29		" 9th	23	8	24	
" 13th	27	1	41		" 12th	19	5	25	
" 19th	27	5	25		" 17th	17	1	36	
Jan. 3rd	38	9	14		" 20th	25	7	17	
" 7th	20	9	39		Jan. 6th	12	7	37	
" 16th	23	4	36		" 9th	18	8	21	
" 23rd	29	9	33		" 21st	20	2	27	
	309	67	294	670		219	66	269	544

Subject E. H. L. Table showing the errors for 100 series of nonsense syllables with pronunciation inhibited by counting.

Dec.7, 9	11.	13.	18.	21.	Jan 2.	6.	9.	15.	18.	Av.
5	5	8	3	6	3	4	2	3	4	4.3
5	4	4	5	4	5	4	3	5	6	4 5
5	7	6	5	6	8	8	5	7	5	6.2
6	6	5	9	8	5	6	7	6	3	6.1
9	5	5	8	6	3	5	5	5	4	5.5
5	6	6	6	4	5	3	5	5	4	4.9
8	7	6	5	6	9	7	4	3	3	5.8
6	6	5	7	5	6	5	4	4	7	5.5
9	6	6	5	5	5	3	5	6	9	5.9
8	5	7	8	9	7	8	5	4	7	6.8
6.6	5.7	5.8	6.1	5.9	5.6	5.3	4.5	4.8	5 2	5.55

Subject E. H. L. Table showing the errors for 100 series of nonsense syllables learned under normal conditions.

Dec.7, 9	12.	17.	19.	23.	Jan. 4.	7.	11.	13.	16.	Av.
4	5	4	4	3	3	1	4	4	2	3.0
2	6	4	5	4	4	2	5	2	4	3.8
7	8	5	3	5	6	3	3	4	5	4.9
7	4	4	2	4	6	2	6	5	6	4.6
5	4	2	3	4	4	5	5	2	2	3.6
6	4	6	2	4	8	6	3	4	7	5.0
5	5	1	3	5	6	5	5	1	1	3.7
5	3	5	5	3	4	5	3	3	6	4.2
4	8	5	5	4	4	5	4	2	5	4.6
5	6	5	4	5	5	1	4	6	4	4.5
5.0	5.3	4.1	3.5	4.1	5.0	3.5	4.2	3.0	4.2	4.19

Subject E. H. L. Table showing classification of errors given in two preceding tables.

SUBJECT. E. H. L.	(c) F.	D.	W.	Total.		(o) F.	D.	W.	Total.
Dec. 7 & 9	50	1	15		Dec. 7 & 9	39	2	9	
" 11th	32	16	9		" 12th	37	2	14	
" 13th	32	10	16		" 17th	31	5	5	
" 18th	41	4	16		" 19th	28	2	5	
" 21st	36	10	13		" 23rd	32	3	6	
Jan. 2nd	45	2	9		Jan. 4th	37	3	10	
" 6th	47	1	5		" 7th	30	1	4	
" 9th	27	9	9		" 11th	33	3	6	
" 15th	35	2	11		" 13th	19	4	7	
" 18th	29	7	16		" 16th	27	3	12	
	374	62	119	555		313	28	78	419

Subject C. G. Table showing errors for 100 series of nonsense syllables with pronunciation inhibited by counting.

Dec. 11.	13.	18.	20.	Jan. 2.	4.	7.	11.	15.	17.	Av.
6	7	10	8	10	9	10	6	7	8	8.1
8	7	10	5	7	7	8	6	7	8	7.3
10	8	7	7	7	7	6	7	8	8	7.5
8	8	8	10	6	10	6	9	6	8	7.9
7	6	10	10	7	6	8	7	6	7	7.4
6	8	7	8	8	7	8	5	7	7	7.2
7	5	7	8	6	9	7	6	5	7	6.7
9	7	9	7	8	8	8	7	7	8	7.8
9	6	10	7	8	8	5	9	7	8	7.7
9	7	7	7	5	7	7	7	8	7	7.1
7.9	6.9	8.5	7.7	7.2	7.8	7.4	6.9	6.8	7.6	7.47

Subject C. G. Table showing errors for 100 series of nonsense syllables learned under normal conditions.

Dec. 12.	14.	19.	21.	Jan. 3.	7.	9.	13.	16.	18.	Av.
5	5	7	6	6	6	6	1	5	6	5.3
8	4	6	7	7	3	6	7	5	6	5.9
7	5	7	5	5	7	6	5	4	7	5.8
7	4	6	7	6	6	8	5	7	5	6.1
7	7	6	3	4	3	4	3	7	7	5.1
4	5	6	7	5	6	6	5	6	5	5.5
5	7	7	7	6	6	4	5	5	5	5.7
5	5	6	6	6	5	7	6	7	7	6.0
7	5	8	8	7	7	5	5	5	7	6.4
4	3	7	7	6	4	5	5	5	6	5.2
5.9	5.0	6.6	6.3	5.8	5.3	5.7	4.7	5.6	6.1	5.7

Subject C. G. Table showing classification of errors in two preceding tables.

	(c)			Total.		(o)			Total.
	F.	D.	W.			F.	D.	W.	
Dec. 11th	66	5	8		Dec. 12th	48	6	5	
" 13th	60	3	6		" 14th	42	3	5	
" 18th	75	3	7		" 19th	53	6	7	
" 20th	70	6	1		" 21st	51	4	8	
Jan. 2nd	60	4	8		Jan. 3rd	49	1	8	
" 4th	66	7	5		" 7th	36	7	10	
" 7th	63	2	9		" 9th	45	–	12	
" 11th	62	1	6		" 13th	33	4	10	
" 15th	62	4	2		" 16th	47	3	6	
" 17th	63	6	7		" 18th	40	1	20	
	647	41	59	747		445	35	91	570

Subject R. G. Table showing errors for 100 nonsense syllables with pronunciation inhibited by counting.

Jan. 26.	28.	30.	Feb. 7.	11.	24.	Mar. 3.	9.	23.	Apr. 3.	Av.
7	7	8	4	7	6	4	4	1	4	5.2
7	6	5	4	3	4	0	1	5	3	3.8
8	8	5	5	6	5	3	4	3	1	4.8
8	9	7	6	6	7	3	8	2	1	5.7
4	4	7	7	7	6	4	4	3	3	4.9
5	4	7	7	7	5	8	4	5	2	5.4
7	4	5	6	8	4	4	4	6	1	4.9
5	5	5	6	7	4	7	3	7	2	5.1
6	6	5	6	7	2	6	6	4	1	4.9
5	5	5	4	3	2	5	8	3	0	4.0
6.2	5.8	5.9	5.5	6.1	4.5	4.4	4.6	3.9	1.8	4.87

Subject R. G. Table showing errors for nonsense syllables under normal conditions.

Jan. 24.	27.	29.	Feb. 10.	18.	25.	Mar. 10.	24.	31.	Apr. 4.	Av.
6	4	5	4	6	4	1	4	2	0	3.6
6	2	4	5	5	5	4	2	3	0	3.6
9	3	4	1	7	4	3	0	0	0	3.1
6	3	5	8	7	4	3	0	0	2	3.8
5	4	6	5	4	4	1	4	3	2	3.8
8	3	4	7	2	4	3	3	2	1	3.7
3	5	1	3	5	3	1	1	1	0	2.3
5	7	6	3	2	0	2	3	1	0	2.9
7	7	6	6	0	4	1	0	0	0	3.1
4	3	4	3	2	3	0	1	4	0	2.6
5.9	4.1	4.5	4.7	4.0	3.5	1.9	1.8	1.6	5	3.25

Subject R. G. Table showing classification of errors given in two preceding tables.

	(c)			Total.		(o)			Total.
	F.	D.	W.			F.	D.	W.	
Jan. 26th	50	1	11		Jan. 24th	38	7	14	
" 28th	39	7	12		" 27th	30	4	7	
" 30th	28	2	19		" 29th	27	6	12	
Feb. 7th	35	2	18		Feb. 10th	29	6	12	
" 11th	34	3	24		" 18th	28	2	10	
" 24th	31	3	11		" 25th	20	3	12	
Mar. 3rd	30	3	11		Mar. 10th	10	1	8	
" 9th	24	7	15		" 24th	8	3	5	
" 23rd	27	–	12		" 31st	8	3	5	
Apr. 3rd	7	2	9		Apr. 4th	4	–	1	
	315	30	142	487		202	35	88	325

SUMMATION TABLE FOR NONSENSE SYLLABLES.

J. P. H.	(c)	69	76	80	81	76	82	79	79	83	77	7.82
	(o)	64	63	66	57	63	71	71	63	68	63	6.49
											D. = 13.3%	
E. C. S.	(c)	72	64	79	66	69	57	61	68	63	71	6.70
	(o)	64	61	60	55	49	54	49	56	47	49	5.44
											D. = 12.6%	
E. H. L.	(c)	66	57	58	61	59	56	53	45	48	52	5.55
	(o)	50	53	41	35	41	50	35	42	30	42	4.19
											D. = 13.6%	
C. G.	(c)	79	69	85	77	72	78	74	69	68	76	7.47
	(o)	59	50	66	63	58	53	57	47	56	61	5.70
											D = 17.7%	
R. G.	(c)	62	58	59	55	61	45	44	46	39	18	4.87
	(o)	59	41	45	47	40	35	19	18	16	5	3.25
											D. = 16.2%	

D. = percentage of difference between series with counting and normal series.
(c) = series with counting.
(o) = series under normal conditions.

A study of these tables shows in all subjects a gradual diminution of error due to practice. An examination of the curves given on pages 473 and 474 shows that in four of the subjects, this was fairly uniform. R. G.'s record, however, shows a very sudden descent of the error curve toward the end. A reference to the dates of the experiments and the fact that during

the latter part of March R. G. served as subject of another research in which the same series of nonsense syllables was used, and received considerable practice in memorizing, furnish an explanation of this deviation from the other results.

The method of each subject was carefully noted, and test series, in which the subject was required to memorize aloud were taken. Although these series were taken primarily simply as a study of method, the quantitative variation for the different subjects due to the addition of the auditory element and emphasizing of the throat movements are so marked that a brief summary of them is given. Five tests, consisting of ten series of ten syllables each, were taken for each subject.

Average	error	for	E. H. L.	= 3.30
"	"	"	C. G.	= 4.55
"	"	"	E. C. S.	= 4.58
"	"	"	J. P. H.	= 6.38
"	"	"	R. G.	= 2.20

Comparing these results with those given in the previous tables, we find a positive improvement of memory, amounting—

For	E. H. L.	to	8.9	per cent.
"	C. G.	"	11.5	" "
"	E. C. S.	"	8.6	" "
"	J. P. H.	"	1.1	" "
"	R. G.	"	10.5	" "

Some allowance must be made in the case of R. G., as these records were taken toward the close of the series of experiments, and were therefore affected by the extraneous practice before mentioned.

It will be remembered that from the beginning no attempt was made to regulate the method of learning the syllables by the introduction of artificial conditions, each subject being left free to pursue the method most natural to him. The number of times the syllables were read during the twenty seconds was therefore dependent upon the individual preference of the subject. The average number of readings for each subject was as follows:

E. C. S., three or four readings during twenty seconds.
E. H. L., two or less " " " "
R. G., rarely more than one reading during twenty seconds.
G. G., two or three readings during twenty seconds.
J. P. H., four or four and a half readings during twenty seconds.

Arranging these results in order of the frequency of reading and comparing them with the percentage of error for each subject, gives the following tables :

	Average Error with Counting.	Average Error in Normal Series.	Read Series.
R. G.	4.87	3.25	1+
E. H. L.	5.55	4.19	2+
E. C. S.	6.70	5.44	3+
C. G.	7.47	5.70	3+ [1]
J. P. H.	7.82	6.49	4+

This result was unexpected, but is so striking as to suggest that the retentiveness which has been ascribed by Ebbinghaus and later experimenters may be due to the amount of time given to each syllable and that the practical problem to be solved for pedagogy is that of distribution of time in relation to the number of repetitions rather than a simple question of the number of repetitions.

While the tables show for every subject an increase of error, varying from 12.6% to 17.7%, due to the introduction of the counting, it still remains doubtful whether the difference can be attributed to the inhibitory effect of the counting upon the muscles, which under normal conditions would furnish the motor expression of the syllables, or to a diversion of attention caused by the introduction of a new factor. This difficulty was fully recognized and various attempts made to meet it. One, which, however, proved unsatisfactory, is noted here, although the test which finally proved most satisfactory is taken up in connection with the later experiments made with the manual alphabet as material. It seemed that if any series could be devised in which the motor idea was originally absent, but might be introduced later, or if this series were of such a character that it could be directly compared with the nonsense syllables series, a verification of the results already obtained might be found.

In any series, whether of figures, letters or syllables, that could be named, the motor idea must be present, therefore the only way of obtaining a series to compare with those already given was to use something which should be unnamed

[1] Toward the close of the experiments this subject changed his method to slower reading.

by the subject. Various Oriental alphabets, and the Braille system used by the blind, were tried, but were all found open to objection. Some were too complicated to be reproduced within the given time, and others suggested objects which could be named. Finally a series composed of a curve and straight lines in different positions was adopted. A complete set of experiments, one hundred series, was carried out with two subjects, but the results were not such as to justify a continuance in the same line. In one subject the percentage of error fell midway between the series with counting and the normal series instead of running parallel with it, as was expected. In the other it differed but a small per cent. from the normal series. This result was evidently due to the imperfection of the material, as it proved suggestive of so many mnemonics that the naming element was by no means excluded. The subject using the most mnemonics had the lesser percentage of error.

A summary of the results derived from an examination of the tables includes the following points :

I. The number of syllables displaced is for every subject less than either of the other two classes of error.

II. For all subjects except one (E. C. S. in the normal series), the number of syllables forgotten exceeds those given wrongly.

III. There are no marked differences in the proportion of three classes of error in the series with counting and the normal series.

IV. The percentage of error is increased to an amount varying from 12.6% to 17.7% for different subjects by the addition of the counting.

In addition to these quantitative results, the study of errors, particularly that of the wrong syllables, furnishes much material that is suggestive. The wrong syllables may be grouped into three classes : I. Those which are mutilated forms of the original syllables. II. Syllables which have been transferred from earlier series, or are mutilations of syllables occurring elsewhere in the same series. III. A residual which can be included in neither of the above classes.

The first class, *i. e.*, mutilations of the original syllables, is the most numerous as well as the most interesting. Displacement of final and initial consonants occur about equally, and these are more numerous than displacements of the vowel.

In several subjects there has been observed a distinct tendency to displace these consonants in accordance with Grimm's law of the interchange of consonants, *i. e.*, *b* and *p*, *t* and *d* are interchanged. Unusual consonants, as final *j* or *h* or initial *x*, are frequently omitted, and in many cases the subject reported something forgotten which was hard to pronounce.[1]

In the study of the second class of wrong syllables, *i. e.*, those transposed from earlier series, great difficulty presented itself, the tracing back of syllables through a large number of series involving much labor and some uncertainty in the results, as syllables similar in sound and spelling were frequently confused. One fact, however, has been clearly deduced : there is a strong tendency of certain syllables to recur in successive series when actually present in only one or at most three series, *e. g.*, one syllable, *ceb*, was found to have been given thirteen times in one hundred series when it actually occurred but twice. This, however, was probably partly due to confusion with the syllable *ced*, which occurred three times during the one hundred series.

The third class of errors, which is numerically the smallest, has yielded no results.

Experiments of the Second Series.

For the second series of experiments an entirely new material was used. This consisted of the printed characters of the manual alphabet. The small cards[2] ordinarily used

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[1] Experiments with series of syllables so arranged as to present special difficulties of pronunciation might furnish interesting results.

[2] These can be obtained from the National Exponent Publishing Co., 69 Lake street, Chicago.

in deaf mute institutions were cut apart and arranged in series of five and ten. *J* and *Z* were excluded, so that with the character &, twenty-five characters indicating positions of the hand were available. These were so arranged that each position occurred the same number of times in ten series, no position occurring twice in the same series.

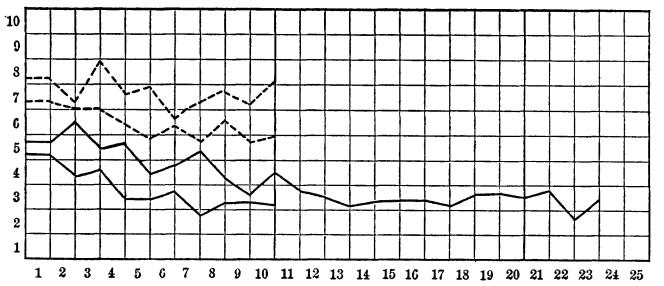
Each subject received sufficient preliminary training to enable him to form the characters with a reasonable degree of facility. The same method of presentation was used as in the case of the nonsense syllables. In the series of five the same intervals, *i. e.*, twenty seconds' exposure and seventy seconds' intermission, were used. In the series of ten, the time of exposure remained the same, but the intermission was doubled to allow for the slower reproduction than in the case of the nonsense syllables. The subject was given at one sitting ten successive series, which he was asked to memorize visually, and to reproduce by forming the characters with his hand as soon as the shutter fell. A series running parallel with this was also taken, in which all conditions remained the same, except that during the twenty seconds devoted to learning the series,the subject was required to form the characters with his hand in addition to the visual reading. These series were taken on alternate days, for the same reason as in the case of the nonsense syllables, *i. e.*, to avoid the interference which occurred when the two series were alternated at one sitting. None of the subjects was familiar with the manual alphabet, and so far as possible the same conditions of experimentation were observed throughout. The same method of recording errors was used as in the experiments with nonsense syllables.

Records were taken on seven subjects, three of whom, E.C. S., E. H. L. and J. P. H., had served as subjects throughout the work with the nonsense syllables. The tables are formed on the same basis as those for the nonsense syllables, the vertical columns showing the errors of the successive series for each day's record, and the horizontal reading the errors of the successive series taken in numerical order for successive days. The summation table shows the decrease in percentage of error for each subject when the characters were

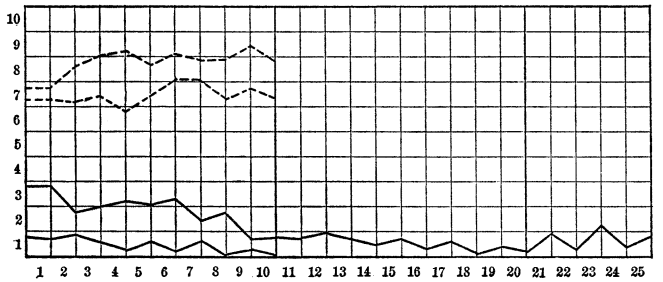
formed with the hand during the learning of the series, and also of a third series, in which the subject was required to count while learning a series visually. This latter series was not alternated with the others, but was taken continuously after the other records were completed. This is more clearly shown by a reference to the curves given on page 474. For the sake of brevity, these series will be referred to as visual and motor series and series with counting.

The curves are plotted on the basis of the total number errors, each point in the curve representing the average error for a series of ten experiments, *i. e.*, for one hundred nonsense syllables or one hundred characters of the manual alphabet, except in series of five, where the calculation is based upon fifty instead of one hundred characters. The figures of the vertical column indicate the number of errors and the horizontal the number of series of ten experiments. The dotted lines represent the curves for the nonsense syllables, the upper curve being for the series taken with counting and the lower the corresponding normal series. The curves formed by the continuous lines represent the manual alphabet series, the upper being for the visual and the lower for the motor series. The continuation of the curve from 10 to 20 shows the effect of the counting on the manual alphabet series, and from 20 onward the effect of discontinuing the counting in diagrams I and II. In V, VI and VIII the counting begins at seven and is discontinued from thirteen onward.

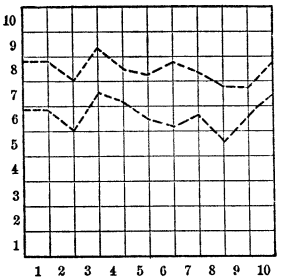
I. Subject E. C. S.



II. Subject J. P. H.

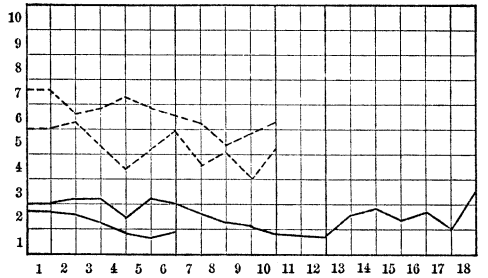


III. Subject C. G.

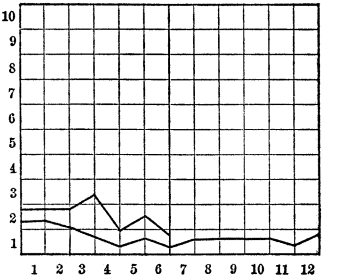


IV. Subject R. G.

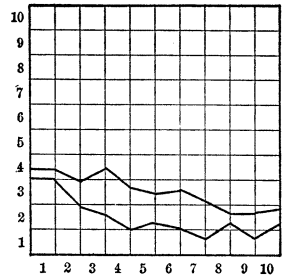
V. Subject E. H. L.



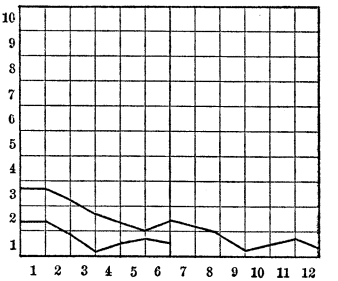
VI. Subject D. H.



VII. Subject A. E. E.



VIII. Subject T. C.



Preliminary record of E. C. S. Series of five.

Motor Series.					Total.	Visual Series.					Total.
Feb. 27.	28.	Mar. 3	7.	10.		F'b. 21	24.	Mar. 2	5.	9.	
0	0	0	1	0	1	1	2	0	0	0	3
1	1	0	0	0	2	1	1	0	1	0	3
0	0	1	0	0	1	2	1	1	0	0	4
0	0	0	0	0	0	2	3	1	1	1	8
1	0	0	1	1	3	2	3	1	0	0	6
0	1	1	0	0	2	2	4	2	0	0	8
2	2	0	2	1	7	3	1	1	2	0	7
0	2	0	0	0	2	3	3	0	1	0	7
1	1	0	2	0	4	2	0	3	0	0	5
2	1	1	1	2	7	4	3	0	0	0	7
7	8	3	7	4	29	22	21	9	5	1	58

Record of E. C. S. Manual alphabet, visual series of ten.

Mar. 13.	19.	24.	27.	31.	Apr. 3.	15.	18.	23.	25.	Av.
3	4	2	4	5	4	3	2	0	0	2.7
4	6	6	2	0	2	2	4	2	5	3.3
5	5	6	6	3	3	3	2	5	2	4.0
7	6	4	4	4	3	4	3	4	4	4.3
4	4	0	8	4	6	6	5	4	4	4.5
5	5	6	5	5	0	6	2	2	4	4.0
7	5	8	3	2	4	5	3	4	5	4.6
6	5	5	2	1	1	2	2	0	5	2.9
3	8	5	7	4	6	3	5	2	1	4.4
3	7	4	6	6	6	7	3	4	5	5.1
4.7	5.5	4.6	4 7	3.4	3.5	4.1	3.1	2.7	3.5	3.98

Record of E. C. S. Manual alphabet, motor series of ten.

Mar. 16.	20	26.	30.	Apr. 2.	4	17.	21.	24.	26.	Av.
2	1	4	0	4	4	1	1	3	0	2.0
4	4	6	0	0	2	0	0	2	2	2.0
3	2	4	2	1	2	1	2	2	2	2.1
5	5	4	2	2	1	1	2	2	3	2.7
5	6	4	3	3	6	3	2	1	3	3.6
4	3	2	3	3	1	3	1	4	2	2.6
6	3	1	3	1	5	3	3	3	2	3.0
5	3	2	3	5	3	3	2	3	2	3.0
4	5	4	5	3	2	2	5	2	2	3.4
4	3	5	3	2	1	2	5	2	3	3.0
4.2	3.5	3.6	2.4	2.4	2.7	1.8	2.3	2.4	2.1	2.74

Record of E. C. S. Manual alphabet, series of ten with counting.

Apr. 28.	29.	30.	May 1.	2.	4.	5.	7.	8.	9.	Av.
0	0	2	2	2	1	1	3	1	1	1.3
3	3	1	0	0	1	1	5	4	2	2.0
4	1	3	2	1	2	2	0	3	3	2.1
4	3	3	2	3	3	3	4	4	2	3.1
2	4	2	2	3	3	2	1	3	2	2.4
3	3	2	3	3	4	3	1	3	2	2.7
3	2	2	3	3	3	2	1	3	4	2.6
4	3	2	3	3	2	3	4	1	4	2.9
3	4	2	3	4	4	3	3	3	2	3.1
3	3	2	3	3	2	2	4	1	2	2.5
2.9	2.6	2.1	2.3	2.5	2.5	2 2	2.6	2.6	2.4	2.47

Preliminary record of A. C. E. Series of five, manual alphabet.

Motor Series.					Total.	Visual Series.					Total.
Mar. 22	23.	25.	28.	31.		Mar. 17	18.	21.	24.	27.	
1	0	0	0	0	1	1	0	0	0	0	1
0	0	0	0	0	0	2	3	2	0	0	7
0	1	0	0	0	1	1	0	2	0	0	3
1	0	0	0	0	1	2	1	3	0	0	6
0	0	0	0	0	0	3	3	1	2	1	10
1	0	0	0	0	1	3	3	1	1	1	9
1	0	1	2	0	4	1	2	3	1	0	7
0	1	0	0	0	1	2	4	2	2	2	12
1	1	0	0	1	3	3	3	0	1	3	10
1	3	0	0	0	4	3	3	0	0	0	6
6	6	1	2	1	16	21	22	14	7	7	71

Percentage of error, 3.2%. Percentage of error, 14.2%.
Dif. =11%.

Record of A. C. E. Manual alphabet, visual series of ten.

Apr. 3	13.	17.	21.	24.	27.	29.	May 2.	5.	7.	Av.
2	1	3	0	0	0	1	0	0	0	.7
7	5	4	0	3	0	1	0	2	0	2.2
4	2	5	4	3	5	1	4	0	3	3.1
2	4	4	2	2	2	2	0	1	2	2.1
4	4	3	1	3	0	4	0	3	1	2.3
3	4	0	4	2	6	4	2	0	0	2.5
3	1	3	4	3	5	2	4	4	4	3.3
3	3	3	5	2	2	5	6	4	3	3.0
5	3	2	2	4	3	2	5	0	2	2.8
2	2	4	5	3	2	0	1	2	2	2.3
3.5	2.9	3.1	2.7	2.5	2.5	2.2	1.6	1.6	1.7	2.43

Record of A. C. E. Manual alphabet, motor series of ten.

Apr. 1.	4.	16.	18.	23	25.	28.	May 1.	4.	6.	Av.
3	1	1	0	0	2	1	0	0	0	.8
3	2	2	0	0	0	0	0	1	1	.9
2	2	2	1	1	0	0	1	0	0	.9
2	2	3	0	2	2	1	2	2	1	1.7
4	1	1	0	2	3	1	0	0	0	1.2
3	2	2	1	3	0	0	1	1	0	1.3
3	3	1	2	3	1	1	0	0	0	1.4
3	3	1	1	0	1	2	3	2	4	2.0
4	3	1	3	1	0	1	2	0	3	1.8
3	0	4	2	2	2	2	2	0	1	1.8
3.0	1.9	1.8	1.0	1.4	1.1	.9	1.1	.6	1.0	1.38

Record of J. P. H. Manual alphabet, visual series of five.

Feb. 8.	12.	15.	19.	25.	29.	Mar. 4.	7.	11.	14.	Av.
2	1	2	2	2	2	1	2	0	1	1.5
2	2	0	1	2	1	1	2	0	0	1.1
3	2	2	3	3	2	2	3	2	1	2.3
4	3	0	1	1	2	1	0	0	0	1.2
2	0	3	3	3	3	0	1	1	1	1.7
5	3	3	3	5	1	1	0	2	0	2.3
1	2	2	3	2	3	1	3	0	1	1.8
2	2	2	1	1	4	3	1	0	1	1.7
4	1	2	1	0	3	2	3	1	3	2.0
3	2	3	3	2	1	1	2	1	0	1.8
2.8	1.8	1.9	2.1	2.1	2.2	1.3	1.7	.7	.8	1.74

Record of J. P. H. Manual alphabet, motor series of five.

Feb. 11.	14.	18.	21.	23.	Mar. 3.	6.	10,	13.	17.	Av.
0	1	0	0	2	0	0	1	0	0	.4
0	1	1	2	0	1	1	1	0	0	.7
1	0	0	0	0	0	0	0	0	0	.1
3	3	1	2	1	0	1	0	0	0	1.1
0	1	0	1	0	0	0	0	0	0	.2
1	0	1	1	1	1	1	1	0	0	.7
1	1	1	0	2	0	0	2	1	3	1.1
1	0	2	1	2	1	2	0	0	0	.9
1	0	1	1	0	0	0	0	2	0	.5
1	1	0	1	1	0	1	1	0	0	.6
.9	.8	.7	.9	.9	.3	.6	.6	.3	.3	.63

Record of J. P. H. Manual alphabet, series of five with counting.

Mar. 20.	24.	25.	27.	28.	31.	Apr. 1.	2.	4.	6.	Av.
0	0	0	1	0	0	0	0	0	0	.1
0	0	0	0	0	0	0	0	0	0	.0
2	1	2	0	4	0	0	1	0	0	1.0
1	0	0	0	0	1	2	0	0	0	.4
0	0	1	0	2	0	0	0	0	0	.3
1	2	0	0	0	1	2	0	2	0	.8
1	3	2	1	0	0	0	0	0	1	.8
2	2	0	0	1	0	1	0	0	0	.6
0	1	2	0	0	0	0	0	0	0	.3
0	0	0	2	0	0	0	0	0	0	.2
.7	.9	.7	.4	.7	.2	.5	.1	.2	.1	.45

Record of D. H. Manual alphabet, visual series of five.

Mar. 31.	Apr. 2.	4.	13	15.	16.	Sum.
2	2	3	3	1	0	11
2	2	3	0	0	1	8
0	2	3	1	2	0	8
2	3	2	0	0	2	9
3	0	2	0	1	2	8
1	1	3	0	1	0	6
2	3	2	0	3	0	10
3	1	2	1	2	0	9
2	3	1	4	3	1	14
1	1	2	0	2	1	7
1.8	1.8	2.3	.9	1.5	.7	90

Av. 1.50.

Record of D. H. Manual alphabet, motor series of five.

Mar. 30.	Apr. 1.	3.	14.	16.	17.	Sum.
0	0	0	0	2	0	2
3	2	2	1	0	0	8
1	1	0	0	0	1	3
0	0	0	1	0	1	2
2	2	0	0	2	0	6
1	0	2	0	1	0	4
2	1	0	1	1	0	5
1	1	0	1	0	1	4
1	2	2	1	0	0	6
3	2	1	0	0	0	6
1.4	1.1	.7	.5	.6	.3	46

Av. .76

Record of D. H. Manual alphabet, with counting.

Apr. 24.	25.	27.	28.	29.	30.	Sum.
0	0	0	0	0	0	0
1	1	0	2	0	0	4
0	0	1	1	1	0	3
2	1	0	0	0	0	3
0	1	0	1	1	1	4
1	0	0	0	1	2	4
1	2	0	1	0	0	4
0	0	2	0	1	0	3
1	1	2	0	0	0	4
0	0	1	1	1	1	4
.6	.6	.6	.6	.5	.4	33

Av. .55

Record of E. H. L. Manual alphabet, visual series of five.

Mar. 8.	20.	25.	30.	Apr. 3.	17.		Sum.
1	1	1	1	0	0		4
5	3	2	0	0	2		12
2	1	2	3	2	1		11
1	4	3	0	3	2		13
0	2	3	2	2	2		11
2	0	2	1	2	2		9
4	1	1	0	3	3		12
1	3	3	2	3	4		16
2	4	2	3	3	1		15
2	2	2	3	3	3		15
2.0	2.1	2.1	1.5	2.1	2.0		118

Av. 1.96

Record of E. H. L. Manual alphabet, motor series of five.

Mar. 18.	23.	27.	Apr. 1.	15.	22.		Sum.
1	1	1	0	0	0		3
0	2	1	0	1	0		4
3	3	2	1	2	0		11
1	1	0	1	0	0		3
1	1	2	0	0	1		5
4	0	1	0	1	1		7
3	1	1	1	1	2		9
3	1	1	2	1	2		10
0	0	1	2	0	2		5
0	4	1	2	1	1		9
1.6	1.4	1.1	.9	.7	.9		66

Av. 1.10

Record of E. H. L. Manual alphabet, series of five with counting.

Apr. 25.	27	30.	May 1.	5.	6.		Sum.
0	1	0	0	0	1		2
1	1	1	0	2	0		5
2	1	1	2	0	0		6
2	1	1	2	1	1		8
2	2	2	0	2	0		8
2	2	1	0	2	2		9
3	1	2	1	0	2		9
2	2	1	1	1	2		9
2	1	2	2	1	1		9
2	1	1	1	0	0		5
1.8	1.3	1.2	.9	.9	.9		70

Av. 1.16

Record of T. C. Manual alphabet, visual series of five.

Mar. 25	30.	Apr. 1.	3.	14.	17.		Sum.
0	1	2	0	0	0		3
1	3	1	1	1	1		8
4	2	2	2	2	2		14
3	3	2	1	0	3		12
3	2	3	4	2	1		15
2	2	3	1	2	2		12
4	2	1	1	0	0		8
3	2	2	0	1	1		9
3	3	1	1	0	2		10
3	3	2	2	3	1		14
2.6	2.3	1.9	1.3	1.1	1.3		105

Av. 1.75

Record of T. C. Manual alphabet, motor series of five.

Mar. 27.	28.	31.	Apr. 2.	4.	15.		Sum.
1	1	0	0	0	0		2
1	1	0	0	1	0		3
2	0	1	2	0	1		6
2	1	1	0	1	0		5
0	2	0	0	0	0		2
1	1	0	2	1	1		6
3	1	0	0	1	0		5
1	1	1	0	0	0		3
1	0	2	1	1	1		6
1	1	2	0	1	0		5
1.3	.9	.7	.5	.6	.3		43

Av. .71

Record of T. C. Manual alphabet, series of five with counting.

Apr. 24.	25.	27.	28.	29.	30.		Sum.
1	0	0	0	0	0		1
1	0	0	0	0	0		1
1	1	0	1	1	2		6
1	1	1	0	0	1		4
2	1	0	0	0	0		3
1	1	0	0	2	0		4
1	1	0	0	1	0		3
1	1	1	0	0	0		3
1	1	0	1	2	1		6
2	2	1	2	0	0		7
1.2	.9	.3	.4	.6	.4		38

Av. .63

SUMMATION TABLE FOR THE MANUAL ALPHABET SERIES.

												Av.
E. C. S.	V.	47	55	46	47	34	35	41	31	27	35	3.98
	M.	42	35	36	24	24	27	18	23	24	21	2.74
	C.	29	26	21	23	25	25	22	26	26	24	
											D. =	12.4%
A. C. E.	V.	35	29	31	27	25	25	22	16	16	17	2.43
	M.	30	19	18	10	14	11	9	11	6	10	1.38
											D. =	10.5%
J. P. H.	V.	28	18	19	21	21	22	13	17	7	8	1.74
	M.	9	8	7	9	9	3	6	6	3	3	.63
	C.	7	9	7	4	7	2	5	1	2	1	
											D. =	22.2%
								Sum.		Av.		%
D. H.	V.	18	18	23	9	15	7	90		1.5		30.0
	M.	14	11	7	5	6	3	46		.76		15.3
	C.	6	6	6	6	4	5	33		.55		11.0
											D. =	14.7%
E. H. L.	V.	20	21	21	15	21	20	118		1.96		39.3
	M.	16	14	11	9	7	9	66		1.10		22.0
	C.	18	13	12	9	9	9	70		1.16		23.3
											D. =	17.3%
T. C.	V.	26	23	19	13	11	13	105		1.75		35.0
	M.	13	9	7	5	6	3	43		.71		14.3
	C.	12	9	3	4	6	4	38		.63		12.6
											D. =	20.7%

V. = visual series.
M. = motor series.
C. = series with counting.
D. = difference in % of error between visual and motor series.

TABLES SHOWING CLASSIFIC'N OF ERRORS FOR MANUAL ALPHABET.

Record of E. C. S.

MOTOR.			VISUAL.			COUNTING.		
F.	D.	W.	F.	D.	W.	F.	D.	W.
1	8	12	4	15	16	2	13	14
3	11	10	1	13	13	–	12	14
1	12	10	1	17	13	–	10	11
2	6	10	2	27	12	–	11	12
–	16	11	3	15	17	1	11	13
3	10	11	–	19	15	–	11	14
1	18	5	2	22	23	–	10	12
5	22	9	4	25	17	–	10	16
1	21	13	1	33	21	–	13	13
2	25	15	3	25	19	–	12	12
19	149	106	21	211	166	3	113	131

F.= characters forgotten; D.= characters displaced; W.= characters wrong.

Record of A. C. E.

MOTOR.			VISUAL.		
F.	D.	W.	F.	D.	W.
–	5	5	–	8	9
–	3	3	1	7	8
1	3	7	1	9	6
–	3	6	2	12	8
1	6	4	2	16	7
3	7	4	3	13	9
–	4	6	3	12	10
7	5	6	7	16	8
7	5	7	14	9	6
8	3	19	9	8	18
27	44	67	44	110	89

Record of J. P. H.

Motor.			Visual.			Counting.		
F.	D.	W.	F.	D.	W.	F.	D.	W.
1	5	3	16	2	10	–	3	4
4	–	4	6	3	9	–	3	6
3	1	3	6	3	10	1	3	3
3	1	5	3	8	10	–	1	3
4	3	2	7	7	7	–	4	3
1	1	1	4	8	10	–	–	2
–	2	4	3	2	8	–	1	4
1	1	4	1	3	13	–	–	1
–	3	–	–	–	7	–	–	2
1	–	2	–	–	8	–	–	1
18	17	28	46	36	92	1	15	29

Record of D. H.

Motor.			Visual.			Counting.		
F.	D.	W.	F.	D.	W.	F.	D.	W.
5	4	5	5	4	9	3	2	2
2	4	5	8	2	8	3	1	2
2	2	3	5	4	14	2	–	4
4	–	1	1	5	3	1	2	3
3	1	2	5	2	8	–	–	4
–	–	3	1	4	2	–	2	3
16	11	19	25	21	44	8	7	18

Record of E. H. L.

Motor.			Visual.			Counting.		
F.	D.	W.	F.	D.	W.	F.	D.	W.
–	8	8	–	14	6	8	5	5
4	1	9	9	1	11	6	2	5
2	3	6	14	1	6	7	1	4
6	1	2	7	2	6	2	2	5
6	–	1	13	4	4	4	2	3
6	–	3	10	6	4	4	3	2
24	13	29	53	28	37	31	15	24

Record of T. C.

Motor.			Visual.			Counting.		
F.	D.	W.	F.	D.	W.	F.	D.	W.
7	1	5	10	5	11	–	2	2
4	3	2	4	10	9	1	1	4
4	1	2	5	8	6	1	–	3
–	2	3	–	1	10	1	–	2
–	2	4	2	3	8	1	3	5
–	1	2	2	4	7	2	2	8
15	10	18	23	31	51	6	8	24

As in the experiments with the nonsense syllables, a study was made of the method of each subject, both from introspective report and the character of the errors.

E. C. S. showed the strongest tendency to mnemonics. There was at first an inclination to give names to the various characters, but this was resisted as introducing a source of error. Open and closed positions of the hand or the number of fingers pointing upward or downward, were then used as a means of classification. Later, a spatial mnemonic was strongly developed, the first and last and fifth and sixth positions being used as points of fixation. An incipient tendency to form the characters with the hand during the learning of the visual series was noticed, and after the characters became familiar, the subject occasionally could not remember whether in the series where motions were required the motions had been made or not, although, at first, a special effort was required to make them, and they were felt to be a hindrance to the visual learning. The preliminary record of the subject, however, shows 11.6% less of error for the motor series than for the visual. In the final record the difference in favor of the motor series was reduced to 11%. The change of method noted for the later series of nonsense syllables to a slower reading of the series was continued in the learning of the manual alphabet series, the series being read from two to two and one-half times during the twenty seconds of exposure. It is to be noted that the total number of errors is less and the relative number of displacements greater than

in the series of nonsense syllables. The smaller number of characters employed would seem to furnish a reason for this result, but the same relation did not hold for all subjects.

Subject A. C. E. A preliminary record taken with a series of five characters, showed a difference of 11% in favor of the motor series. The difference is reduced to 10.5% in the final record taken with a series of ten. There was with this subject a distinct consciousness of the advantage gained by introducing the motor element, and a much greater degree of confidence was shown in the motor than in the visual series. There was a strong tendency to make the movements during the learning of the visual series. In some instances there was a conflict between the visual and motor images, the statement being made, "It looks like this, but it feels like this." Although decision was sometimes made in favor of the visual image, the motor image was in the majority of cases the correct one. This subject was remarkable for the persistence of the memory images, being able to recall a series after considerable intervals of time had elapsed. In one case a series was correctly recalled after an interval of two hundred and seventy seconds, the time of exposure having been twenty seconds. In the later experiments the method of this subject was chiefly elimination, the possible characters being formed with the hand, and decision, guided partly by the feeling of the hand and partly by the visual image, called up simultaneously with the movement. The series was rarely read through more than once, and in some cases a series had to be thrown out because the subject failed to read it to the end. This record has the least percentage of error found in any case, showing for the motor series only 138 errors for one thousand characters, and for the visual series only 243 errors for the same number.

Subject J. P. H. Little conscious aid was derived by this subject from the introduction of the motor element, except in the practice series, when it at first seemed a help, the feeling of position seeming to reinforce the visual image. Later as the motions became more automatic, they seemed to the subject more of a hindrance than a help in so far as they were noticed at all. The record, however, shows a difference of

22.2% in favor of the motor series, and an incipient tendency to motion was especially marked. In a large number of cases the character was either partially or completely formed by the hand several seconds before it was recalled visually, and in a number of cases the character was correctly formed by the hand, but given up as forgotten by the subject. No visual attention was given to the hand by any subject after the first few practice series.

Subject D. H. This subject made from the first a strong effort to exclude all forms of mnemonics, and to make the memorizing purely visual. The making of the characters was a conscious effort, and in no case was the tendency to form the characters unconsciously, noted. The average number of times of reading the series was two and one-half.

Subject E. H. L. The introspective report of this subject shows the visual image to have been most prominent in consciousness, though during the motor series, the motor image was occasionally distinguished. Little use was made of mnemonics, though the relative positions of the characters were sometimes used as a means of recall. Attempts at naming were very infrequent, though occurring in a few cases.

Subject T. C. This subject showed a slight tendency toward naming the characters, and a somewhat uneven distribution of attention was noted, any character which appeared difficult receiving more attention. In the series in which the characters were not formed with the hand, the visual image was the only one noticed by the subject, and no case of unconscious reproduction of the characters was noted. In the motor series the motion of the hand followed the visual idea without consciousness of effort, but in no case did the motion precede the visual image. The average number of readings given to the series was two and one-half times.

The memory span of each subject was originally tested by a graded series, and in cases where great variability in the results occurred from the use of the longer series, the series of five was used as giving more satisfactory results, although preventing a direct numerical comparison with the series in which ten characters were used. A study of the distribution

of error, and comparison with the nonsense syllables series for each subject, gives the following results:

For E. C. S. displacements are more frequent than wrong characters in both visual and motor series. In the series of nonsense syllables, the reverse was the case. The absolute number of errors is less than in the series of nonsense syllables.

For A. C. E. in the motor series the displacements are more numerous than wrong characters; in the visual series the wrong characters are the more numerous. This accords with the fact that the motor consciousness was very strong in this subject.

For J. P. H. the wrong characters were more numerous in both the visual and motor series and the same was true for both series of nonsense syllables.

For D. H. wrong characters were more numerous than displacements in both motor and visual series.

For E. H. L. wrong characters were more numerous than displacements in both motor and visual series, and the same was true for the two series of nonsense syllables.

For T. C. wrong characters were more numerous than displacements in both motor and visual series.

The total number of errors for subjects having records for both nonsense syllables and manual alphabet series is, in all cases, less in the manual alphabet series, though in the case of E. H. L. the records are not numerically comparable. The smal er number of characters available for the latter series, in part, accounts for this.

There is, in the manual alphabet series, an increase of error in the second half of a series of ten experiments. (One exception to this occurs, T. C. in the visual series.) That this is probably due more to interference than fatigue is shown both by the introspective report of the subject and the record of errors.[1] Positions of the hand which have occurred in previous series were introduced, frequently in the same serial

[1] Cf. Bergström, "Experiments upon Physiological Memory by Means of the Interference of Associations," AMERICAN JOURNAL OF PSYCHOLOGY, V, 1892-93, 356 ff., and VI, 1893-95, 267 ff.

position which they occupied in the original series. Also, if in any case a series was shown and partially learned, but thrown out in consequence of some violation of experimental conditions, the characters of this series showed a tendency to recrudescence throughout the remaining series of the experiment.

The summation table shows for the motor series a percentage of error varying from 10.5% to 22.2% less than in the case of the visual series.

A study of the characters given wrongly was also made, as in the case of the nonsense syllables. All the errors were counted and tables made showing the number of times each letter occurred in place of another.

No quantitative result has been derived from this tabulation, but a careful comparison with the positions of the hand represented by the letters discloses three well-marked groups of errors:

I. Errors arising from similarity, in which the wrong letter bears either a visual or a motor resemblance to the correct letter. In those bearing a visual resemblance, the naming element is probably present to some extent, a classification into open and closed positions of the hand being made. In some cases, this seems to take the form of contrast, a pairing off of letters formed by opposite motions taking place, *e. g.*, q and g. The interchange of b and m, which have no likeness visually, furnishes an example of motor similarity, as may be readily tested by forming the letters with the hand.

II. Those letters which have occurred in the same serial positions in earlier series tend to recur as errors in later series. This class of errors increases in the later members of ten successive series, and the error tends to repeat itself after having once occurred. This was most marked when a series partially learned, or accidentally seen, was thrown out, the letters of such a series persistently intruding themselves into those given later, as if, having failed to find their proper motor discharge, there was an interference with the later mental images.

III. After all errors which can be classified under either of the preceding rubrics are excluded, there is a residual for

which no explanation, save that of chance occurrence, is apparent.

During the experiments with the manual alphabet above recorded, it occurred to the writer that these series might be utilized as a test of the automatic character of the counting in the series of nonsense syllables. The manual alphabet furnished a visual series, in which the naming element was at a minimum, and the motor element introduced through muscles, in which counting could produce no interference. If, then, the difference in error found in the series of nonsense syllables were due to a distraction of attention, the same result should occur in the manual alphabet series.

Five subjects were experimented upon, three of whom were also subjects of the experiments with nonsense syllables. Reference to the tables and to the curves given on page—— show the result. In every case the curve shows a slight but well-marked decrease of error, which may be fairly interpreted as a continuation of the effect of practice. A still more noticeable fact is the smoothing out of the curve. Reference to the tables will show that not only is the variation in the curve from day to day greatly lessened, but the mean variation of the daily record for each series of ten experiments is also reduced, indicating that the counting actually steadied rather than distracted the attention. With three of the subjects, experiment was continued for a few days with a cessation of the counting. One subject shows a decided rise in the error curve, and in all three the variation from the smoothing out of the curve during the counting is marked. From these results the conclusion seems justifiable that the difference found in the two series of experiments with nonsense syllables was due not to a distraction of attention caused by the introduction of a new factor, but to the inhibition of the motor expression.

As a conclusion from the various experiments represented in this study, can it be fairly assumed that out of the memory complex, the motor element has been quantitatively differentiated and its exact influence measured? To the question in this form the answer must be no. The parallel series were made, as nearly as might be for experimental purposes, to

differ only by the one condition of the introduction of a motor element, but the motor element was by no means excluded from the series called visual, but which was, in reality, a complex of visual, auditory and motor images, for though actual muscular movements were absent, the idea of movement was never entirely excluded, as was shown by the report of the methods used by the various subjects. The difference between the series, then, is not to be explained as a difference between a complex of visual, auditory and motor elements, in which the visual element predominates and a similar complex to which the expression of the motor idea is added.

To those who have served as the subjects of the prolonged and tedious series of experiments, I wish to take this opportunity of expressing my hearty thanks, and especially to Dr. Sanford, who has not only served as subject of the experiments throughout the year, but has furnished constant inspiration by his interest and helpful suggestions.